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Geology of Smoke Hollow Area 8 Miles Southeast of Deerlodge, Powell County, Montana

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GEOLOGY OF SMOKE HOLLOW AREA 8 MILES SOUTHEAST OF DEER LODGE, POWELL COUNTY, MONTANA

by
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A Thesis
Submitted to the Department of Geology
in partial fulfillment of the
requirements for the degree of
Bachelor of Science in Geological Engineering

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GEOLOGY OF SMOKE HOLLOW AREA 8 MILES SOUTHEAST

OF DEER LODGE, POWELL COUNTY, MONTANA

Introduction

This investigation was undertaken primarily as a problem in geologic mapping, including a study of stratigraphy, igneous phenomena, and geologic structure; and is written as a thesis in partial fulfillment of the requirements for a degree of Bachelor of Science in Geological Engineering at the Montana School of Mines. Figure 1 shows the location of the area which is about 8 miles east of Deer Lodge, Montana in Powell county.

Fig. 1.

The stratigraphy was studied as to the character, age, and sequence of the geologic formations that are exposed. The conclusions were based principally on the field relationships and lithology because no fossils were found.

Igneous activity, such as the intrusion of the batholith, the associated dikes, and lava flows, and its relation to the structure was studied.

The Helena Mining District Report included a map of this area. Being only a generalized map of the area, it was not detailed. This report is the result field work and furnishes the desired detail to the area.

The bulk of the field mapping was done in the fall of 1949. Late snows in the spring of 1950 prevented extension of the survey as desired by Mr. Robertson. The survey was made on aerial photographs and transferred to the final map included in this report. The survey covered a general area about 5 miles long and up to 3 or 4 miles wide.

The author wishes to acknowledge the numerous suggestions and criticisms offered by Dr. E. S. Perry and Mr. Forbes S. Robertson. The writer also wishes to express his appreciation for the help given him by Dr. Alvin M. Hanson.

Location and Accessibility

The Burnt Hollow area is approximately 8 miles southeast of Deer Lodge, Montana and it is located in Powell County. The area included on the map lies in Township 6 North, Ranges 8 and 9 West, and Township 7 North, Ranges 8 and 9 West of the principal meridian.

Several good roads lead into the area from Deer Lodge. One road leads to the northern section of the area, while a second road leads into the southern part of the area and then continues on to Boulder, Montana. These gravel roads are in good condition, but they become impassable during winter, and continued to be so up the second week of April, 1950.

Climate and Vegetation

The temperature ranges from extremes of 90 degrees in the summer to a minus 40 degrees Fahrenheit in the winter. The annual mean temperature is about 44 degrees. Wide daily temperature variances are not common. The climate is semi-arid with an annual rainfall of 15 to 20 inches with most of the precipitation coming in the winter and spring.

The area lies in the Deer Lodge National Forest. Medium sized pine, fir, and spruce are abundant in the more elevated regions included in northeastern part of the map. Poplars and willows grow in the gulleys of the foothills that lie between the mountains and the main valley. Sagebrush is common in the lower slopes, but grasses form the major vegetation in the area.

Ranching is the major industry, the foothills covered with luxuriant grass providing good feed for many cattle. Some of the land is capable of growing alfalfa and hay, but farming is difficult in this foothill area and other crops are not encountered except in the valley proper.

Field Work

The field work necessary in connection with this problem was done on Saturdays and Sundays in October and November, 1949 and again in March and April, 1950 whenever weather conditions were suitable. Cold weather and heavy snowfalls limited the field work to a total of 10 working days. The late adverse field conditions resulted in the discontinuing of field work due to lack of time for the preparation of the map and report.

The area was mapped with the aid of U. S. Forest Service aerial photographs to a scale of 1/23,000. The contacts between the sedimentary and igneous rocks were sketched directly on the photographs and then transferred to the ultimate map.

The field work also included physiographic and geologic observations taking of photographs, and collecting sample of the sedimentary and igneous rocks.

Physiography

The Burnt Hollow area is in the foothills forming the western extremities of the East Ridge Range, a northerly trending mountain range of the Rocky Mountain physiographic province. The peaks reach elevations of from 6000 to 7000 feet, but there is no dominant crest except that of Mount Powell (10,145Ft.) about 15 miles West of the area. The east Ridge Range is mainly semi-rugged ridges dissected by stream erosion.

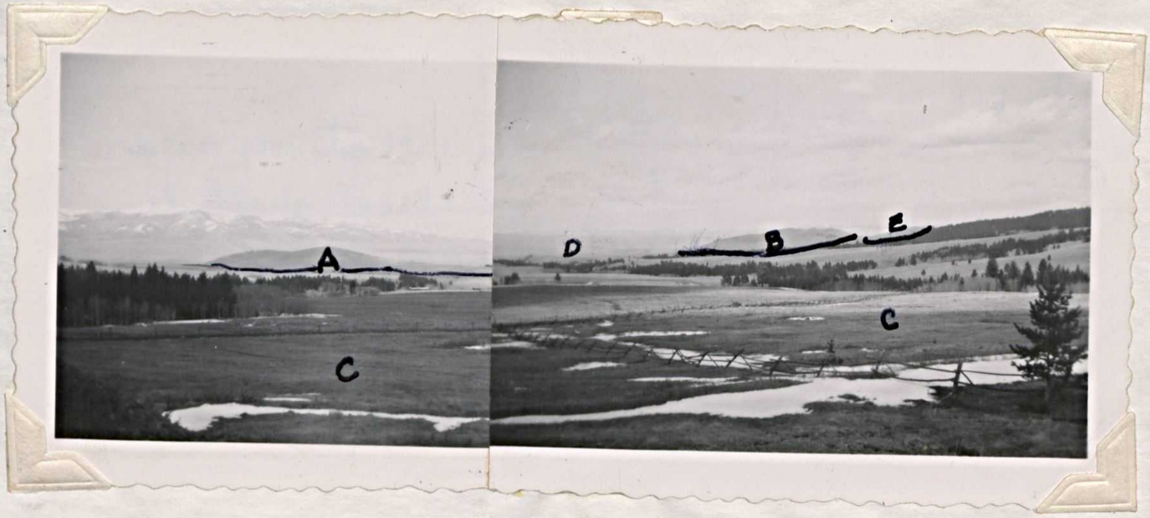


Plate 1.

Looking west over area.

(a) Quadrant quartzite.

(b) Tertiary rhyolites.

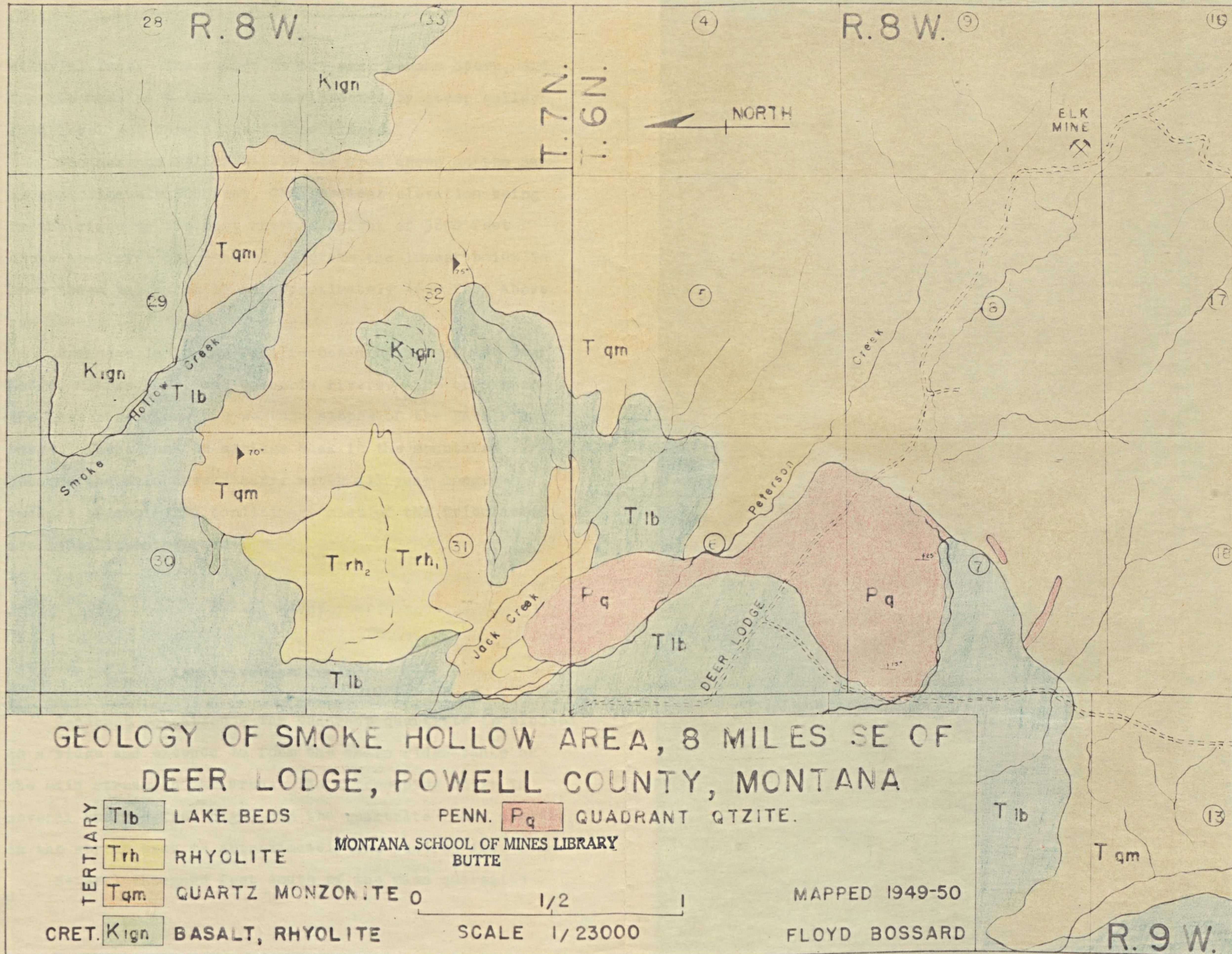
(c) Quartz monzonite.

(d) Lake beds.

(e) Cretaceous igneous.

Level areas in the ranges west of Deer Lodge valley, which have an elevation of about 8,500 feet, may be remnants of an old erosion surface which probably was formed during the Tertiary era, and then uplifted to its present position. The present topography is the result of renewed elevation and stream erosion. No positive evidence of glaciation was observed in the immediate area of Burnt Hollow. Lost Creek valley is the nearest evidence of intence glacial activity. It is a broadly U-shaped valley, boardered by hanging valleys.

The area surveyed is mainly gentle foothills and



R. 8 W.
R. 8 W.
R. 9 W.
T. 7 N.
T. 6 N.
NORTH
ELK MINE
28
33
4
9
16
29
32
5
8
17
30
31
6
7
18
13
Kign
Kign
Kign
Tqm
Tqm
Tqm
Tqm
Tlb
Tlb
Tlb
Tlb
Tlb
Trh2
Trh1
Pq
Pq
70°
75°
Smoke Hollow Creek
Jack Creek
Peterson Creek
DEER LODGE
GEOLOGY OF SMOKE HOLLOW AREA, 8 MILES SE OF DEER LODGE, POWELL COUNTY, MONTANA
TERTIARY
Tlb LAKE BEDS
Trh RHYOLITE
Tqm QUARTZ MONZONITE
CRET. Kign BASALT, RHYOLITE
PENN. Pq QUADRANT QTZITE.
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0 1/2 1
SCALE 1/23000
MAPPED 1949-50
FLOYD BOSSARD

alluvial fans. The ridges to the east become steep, and for the most part the area is dissected by steep gulleys that level out toward the higher ridges.

The maximum relief within the area shown on the map is approximately 500 feet, the greatest elevation being on the ridge to the east where a height of 5800 feet above sea level is attained, whereas the lowest point is Deer Lodge valley which is approximately 4600 feet above sea level.

Drainage is to the Pacific Ocean by way of the Deer Lodge, Clarks Fork, and Columbia rivers. The creeks of the area rise along the western slopes of the East Ridge range. There must be springs back in the mountains because the main creeks carry water all year long. Because of semi-arid conditions, most of the tributaries are intermittent streams.

STRATIGRAPHY

Pennsylvanian Series

Quadrant Formation - The Quadrant quartzite is exposed as a ridge and extends to form the sharp ridge-banks of the main stream in the area. The outcropping ridge is several hundred feet high, and the quartzite ledge exposed in the stream bank is approximately one hundred feet high.

Several thousand feet south of the main quartzite ridge, several outcrops of the quartzite were encountered. Specimens of these outcrops correspond to those found on the ridge.

Plate 2.

Quadrant quartzite ledge.

The formational dips range from 15 degrees on the western extremity of the ridge to approximately 25 degrees to 30 degrees dip of the beds located on the top of the ridge and toward the center of the outcrop. The quartzite ridges to the south do not have any bedding relation to the main body. Even within the outcrops themselves, the dips were very irregular, so no readings were taken.

Surrounding these quartzite outcrops is the main body of the batholith. Therefore the author is of the opinion that the small quartzite hogback ridges are roof pendants of the Quadrant formation isolated but not entirely enveloped and devoured by the batholith. The irregular dip of the main quartzite outcrop, coinciding with the very irregular pattern of the isolated quartzite outcrops, indicates that stresses set up by the intruding magma disrupted the overlying formations, engulfed masses of the same, and isolated bodies of the quartzite, entirely disrupting the sediments.

Plate 3.

Isolated quartzite outcrops, roof pendants.

<u>Metamorphosed Quadrant Quartzite</u> - This was illustrated by a contact exposed by stream erosion. The basal fine-grained quartzite member was changed to a glassy, aphanitic quartzite. Some distance away, the middle or dirty quartz member was metamorphosed to an almost cherty quartzite. This chert-like rock graded from light-green to light-brown colors. Approximately 30 to 40 feet of the Quadrant formation was thus metamorphosed.

The Quadrant formation is approximately 500 to 600 feet thick in the Helena area. No where was the author able to find any evidence of the local phosphate bed that is supposed to overlie the formation not so very far to the north.

The typical specimen is a light-grey rock of dense almost cherty texture. This massive, thick bedded quartzite weathers to an orange surface. Outcrops show typical rough hackly surfaces. The bedding of the outcrops is difficult to recognize.

Plate 4.

Blocky quartzite outcropping (green, blue, grey).

The Quadrant formation has gradational features. The base is dirty grey and composed of rather uniform quartz grains less than a mm. in diameter. There is a carbonate in the interstices between the grains, as indicated by the application of a drop of hydrochloric acid. Possibly, the carbonate serves as a cohesive agent and cements the grain particles. Most probably the carbonate was deposited by percolating ground-water.

The bulk of the formation is a grey or light-brown rock that becomes black over a wide extent. This darker material almost approaches a chert. The individual sand grains cannot be recognized by the eye. The quartzite is very impure and seems to be gradational between a sandstone or quartzite and a shale. It may be that this upper member was not reworked to the extend that the basal member had been. This is supported by the belief that the sea bottom was becoming elevated and exposed to erosion during late Pennsylvanian. This movement would cause the mixing of silts and clay with quartz grains giving an impure sediment.

The upper member of the Quadrant formation is almost a shale. The bluff outcrops so prevelent in the low part disappear toward the top of the formation. Outcrop were difficult to locate and no good quartzite specimens were found.

Plate 5.

(a) Basal quartzite

(b) Shaley quartzite

(c) Metamorphosed quartzite

Intense metamorphism took place at the contact between the batholith, and the part of the formation that forms the cliffs along the streams has almost no discernable dip. This discordance of dip as compared to the main ridge outcrop seems to indicate that there is a fault somewhere in the vicinity of where the main road crosses the Quadrant. Also, the topography along the stream is a flat ridge about 150 to 200 feet below the general elevation of the main ridge. This would suggest a fault displacement.

Cretaceous Igneous Rocks

In the district the Cretaceous igneous flows are an andesitic stage of igneous activity represented by a very diversified group of rock classified megascopically; basalt, diabase, andesite, latite and trachyte with varying types of groundmass and phenocrysts. The vent for the eruption of these rocks was in the vicinity of Thunderbolt Mountain, east of Deer Lodge.

On the steeper slopes, the andesites form bold outcrops, but in the area mapped, the rolling topography eliminated the possibility of rugged features formed by the igneous material. In a broad way the flows are of similar appearance, fine grain and dark color. Where, however, the tachytes and lighter colored andesites prevail, the outcrops weather to light grey or white.

The only place where the flows could be differentiated was on a small hill in sec. 3, T 7 N., R. 8 W. Here a basalt appearing flow, later classified petrographically as a trachyandesite, overlies several flows megascopically classified trachyte and andesite, later classified petrographically as rhyolites. The other Tertiary igneous outcrops in the area are all of the darker trachyandesite flow.

The dark flow resembling basalt, a dark-bluish-black aphanitic rock carrying obscure phenocrysts, is a fresh looking rock and shows flow banding only on the weathered surface. With it, however, are associated other varieties, which exhibit an obvious divergence. These show small scattered phenocrysts of plagioclase and biotite in a groundmass of flinty texture and displaying flow streaking.

Petrography

The bluish-black aphanitic rock shows a porphyritic texture. The andesite with the prominent tabular feldspar crystals contains phenocrysts of plagioclase near Ab, An, and of chloritized and sericitized femmic minerals in a cryptocrystalline matrix. Both are poor in femmic minerals. The rock described megascopically as trachyte and petrographically as rhyolite is characterized by the occurrence of feldspar in a cryptocrystalline groundmass. Streakiness and flow banding are nearly universal.

Slide 2. The megascopic classification of this rock was a basalt because of the apparent large femmic mineral content. Under the microscope the phenocrysts occupy about 20 per cent of the total volume. The matrix has a

Plate 6.

Megascopic basalt.

granular texture. The petrographic analysis identified the essential constituents as 79.2 per cent plagioclase, less than one per cent of quartz and biotite, and 20.0

Plate 7.

Plagioclase carlsbad-albite twinning.

per cent orthoclase. The plagioclase is an andesine with an Ab-An ratio of 56-44. There was a pyroxene that resembled augite, but defied classification. Sericite and saucerite, and kaolinite and calcite are the secondary products of the femmic minerals and feldspars respectively.

Johannsen's classification - trachyandesite.

__Slide 3.__ The megascopic description of this rock was a leucotrachyte. It possesses a poikolitic texture with phenocrysts amounting to about 15 per cent of the total volume. The primary structure shows flow relationships.

Plate 8.

Vein-like quartz in leucotrachyte.

A petrographic analysis of the specimen identified the essential constituents as 26.6 per cent quartz, 5.1 per cent plagioclase, and 68.3 per cent orthoclase. Magnetite

Plate 9.

Orthoclase altering to kaolin.

and an amphibole, probably hornblende, are the accessory minerals. The hornblende is altering to chlorite and sericite. Sericite, kaolin, and calcite are the weathered products of the orthoclase.

Johannsen's classification - rhyolite.

Slide 5. In the hand specimen this rock was identified an an andesite. Under the microscope, the phenocrysts constitute about 5-10 per cent of the total volume of the

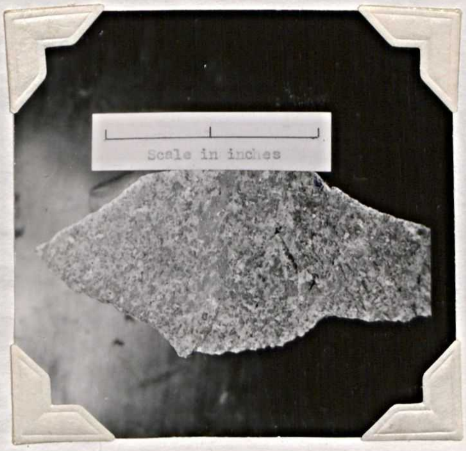

Plate 10.

Andesite.

rock. The predominant microscopic structure visible is the outstanding flow structure exhibited. Also in the direction of flow there are quartz vein-like aggregates.

Plate 11.

Mortar or mylonitic structure is the secondary feature.

The orthoclase phenocrysts show a pronounced microperthitic structure. The essential mineral analysis includes 58.6 per cent orthoclase, 35.4 per cent quartz and 6.0 per cent plagioclase. The accessory minerals are augite, magnetite, and biotite. Kaolin and limonite are the weathered products of orthoclase and femmic minerals respectively. Microcline was identified among the orthoclase phenocrysts. The plagioclase was identified as the andesine with an Ab-An ratio of 60-40.

Johannsen's classification - rhyolite.

Tertiary Quartz Monzonite

Quartz monzonite is the predominant rock exposed throughout the region. This outcrop is a western front of the Bou

Plate 12.

Quartz monzonite boulder outcrop.

The quartz monzonite weathers in characteristic fashion, forming huge bowldery outcrops. The exposed outcrops weather readily, exposing feldspar crystals.

Visible striations indicate that the larger crystals are plagioclase. Some of the crystals are up to 1.5 cm., but they average 0.7 to 1 cm. Joint patterns are rather characteristic in the granite. They are usually a foot or two or even more apart. Readings were taken at several particularly good outcrops and the planes of parting had a general E to W strike and a high angle of dip (70 to 75 degrees).

In the hand specimen of the quartz monzonite, the orthoclase is light green, and noticeable pink plagioclase feldspar are present. The weathered rock is very powdery.

Petrography

Fresh samples of the quartz monzonite were very difficult to find. The author thought that he had obtained good samples at a mine dump and at an outcrop

Plate 13.

(a) Fresh granite.

(b) Weathered granite.

exposed by a slide. But upon analysis of specimens in thin section under a petrographic microscope, the feldspars, mica, and amphiboles were highly altered.

In the hand specimen, the rock is distinguished as a granite. But under the microscope the true character of the rock becomes visible. It is, however, not a true granite, but is accurately designated a quartz monzonite. The rock is composed in the order named essentially of orthoclase, quartz, plagioclase, biotite, and hornblende. It is rather homogeneous in composition, small grained, and somewhat equigranular.

Sample 1. Under the microscope the specimen has hypautomorphic granular texture. The feldspar phenocrysts are larger than the quartz, on the average. The petrographic analysis gave the following results; essential minerals included 26.4 per cent plagioclase, 6.2 per cent biotite, 38.4 per cent orthoclase, and 23.7 per cent quartz. Accessory minerals include hornblend, magnetite, and a basaltic hornblende named lamprobolite. The orthoclase is

Plate 14.

Lamprobolite.

altering to kaolin, and the biotite and hornblende are altering to sericite. Albite twinning gave a high extinction angle of reading of 21 degrees, resulting in an Ab-An ratio of 62-38. A suitable combined albite-carlsbad twin gave the two extinction angles as 21 and 11 degrees respectively. Transferring these values to the proper graph fixed the Ab-An ratio at 60-40. So the two methods check each other and determine the plagioclase as andesine.

Johannsen's classification - adamellite.

Sample 2. This phaneritic specimen also has a hypautomorphic granular texture. Feldspars again have the largest grain size. The essential minerals include 30.6 per cent plagioclase, 36.4 per cent orthoclase, 19.9 per cent quartz, and 9.7 per cent biotite and hornblende. The biotite and hornblende are about equal. Magnetite, apatite, and sphene are the accessory minerals identified. Again kaolin is prominent throughout the orthoclase. Sericite, and limonite are weathering products of the femmic minerals. The extinction angles of plagioclase carlsbad twins and combined carlsbad-albite twins determine the Ab-An ratio at 65-35, in the andesine range.

The most conspicuous characteristic of this thin section is that the matrix is mainly perthitic orthoclase.

Johannsen's classification - adamellite.

Sample 3. Under the microscope the specimen has a hypautomorphic granular texture. The feldspar phenocrysts give it the porphyritic character. The essential minerals include 24.0 per cent quartz, 5.8 per cent biotite and hornblende, 28.6 per cent plagioclase, and 41.5 per cent orthoclase. The accessory minerals are zircon, magnetite, and apatite. Sericite and chlorite are the weathering products of the femmic minerals and the orthoclase weathers to kaolin. In addition to the usual albite and combined albite-carlsbad twinning, the plagioclase is andesine with Ab_{60}-An_{40}. Phenocrysts of orthoclase were slightly perthitic. The biotite showed pleochroic colors from brown to tan.

Johannsen's classification - adamellite.

The petrographic analysis generally agree with those made on other portions of the batholith.

Eocene was probably the age of intrusion of the quartz monzonite.

Tertiary Rhyolites

The rhyolites of the Smoke Hollow region were laid down after the laying down of the Cretaceous andesites

Plate 15.

Tertiary deposits, ridge.

and basalts. This was clearly proved to be the case because in the lower half of sec. 31, T. 7N., R. 8W., the rhyolitic beds are underlain by an outcrop of the Cretaceous material. The contact is clearly visible in the field.

These rhyolites also were later than the quartz monzonitic intrusion of the Boulder Batholith. The author believes this was readily illustrated in the extreme eastern outcrop of the rhyolites. Here is a contact between the batholith and the lava flow. A conglomerate separates the lava from the quartz monzonite. This conglomerate is composed of granitic and quartz pebbles cemented together by a lava groundmass. The granite is somewhat metamorphosed. Feldspar phenocrysts can be seen as they were exposed by weathering of the original granite.

Plate 16.

Conglomerate, granitic pebbles in lava groundmass.

The quartz within the granite pebbles has become very crystalline. Also the quartz that weathered out of the granite and was laying on the surface when the flows came have been effected by contact metamorphism and the conglomerate looks like quartzite over small distances. The material cementing the conglomerate is the same rhyolitic material that lies directly above the conglomerate.

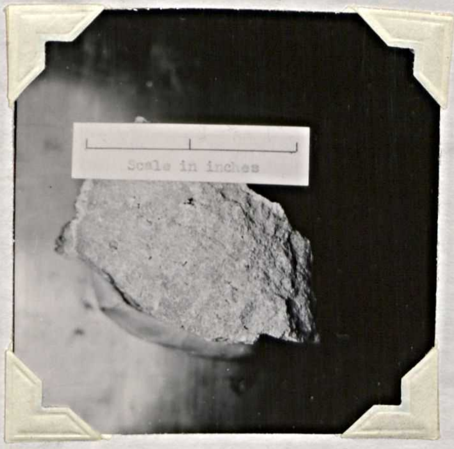

Plate 17.

Tertiary lava.

The Tertiary rhyolites were differentiated into two distinct lava flows. The first flow is brick-red in color. The weathered surface is little different from a new fracture surface in both color and texture. The only difference is that the weathering exposes small, rounded, brown-blebs of an undetermined mineral. The rock itself is characterized by small cracks or gas pockets and openings throughout. Quartz is present as crystalline quartz within the rock itself, and quartz can be seen filling the cavities formed by escaping gas. This lower flow is not too resistant to weathering. The flow structure of this formation dips such that a sloping hill is formed. The rhyolite outcrops on the hill are sheets following the slope. The formation is little inclined to form bluffs or cliffs.

The second flow (T rh_2) is quite a bit darker than the first. It grades from dark browns to dark grey. The vesicules formed by escaping gas are more numerous and are generally quite a bit larger than those in the lower flow. The vesicules total up to 10 per cent of the total volume of the rock. As in the case of the first flow these vesicules, for the most part, contain quartz that form amygdules and a few geodic structures. Percolating water has effected weathering to a highly advanced state. Limonite is the most noticeable weathered product. It is found throughout the rock because the loose compaction is perfect for percolation. This lava flow forms cliff-like outcrops. The outcrop is blocky, and the talus below the cliffs is quite significant in size. This uppermost rhyolite flow is more resistant to weathering than the underlying flow. It is resistant enough to form the most pronounced physiographic feature in the area, excepting the granite ridges. The total thickness of the rhyolite lavas is about 400 feet in the area.

Petrography

A petrographic microscopic analysis of the Tertiary rhyolite identified it petrographically as leuco sodaclase trachyte. Under the counting device, the essential minerals and their percentages was as follows; less than one per cent of quartz, 4.6 per cent of biotite, and basaltic hornblende 78.3 per cent orthoclase, and 17.3 per cent plagioclase. By recording several extinction angles of crystals of plagioclase with albite twinning, the greatest extinction angle was found to be 22 degrees which gave an Ab-An ration of approximately 60-40. This put the plagioclase within the andesine range. No suitable carlsbad-albite twin could be found, so no check was made. Using the petrographic data found and substituting the values in Johannsen's quartz-orthoclase-plagioclase triangle, the rock fell into the 1210 E area, and classified as a leuco sodaclase trachyte.

The most notable feature of the thin section under the microscope was the high percentage of voids. About one third of the rock is actually vesicules and spaces. The microscope confirms the advanced state of weathering. Limonite is the main product. The crystals were easily recognizable under the microscope. This is in direct contrast with several of the earlier flows where the groundmass was too fine even under the microscope to work with. There was very noticeable flow structure illustrated by small elongated microlitic plagioclase feldspar crystals in the matrix. The crystals were oriented to a high degree forming a very noticeable pattern. The plagioclase exhibits albite twinning, combined carlsbad-albite twinning, and pericline twinning. The plagioclase also exhibited numerous instances of zoning which illustrates the varying composition of the solidifying magma.

The orthoclase feldspar included carlsbad twinned crystals as well as non-twinned crystals.

Plate 18.

Pericline twinning.

In the complete mineral analysis, the essential minerals included biotite, quartz, plagioclase, and orthoclase. The accessory minerals are olivine, magnetite, hornblende, and an undetermined amphibole. Limonite, sericite, kaolin, and hematite were the secondary minerals observed.

This was the only thin section made of the Tertiary rhyolites and it was from the first lava flow.

Tertiary Lake Beds

The Tertiary lake beds constitute a superficial formation of silt, sand, gravel, and angular cobbles indicative of lake origin. The upper limits are about 300 feet above the present valley stream channel. The thickness couldn't be estimated. The deposits form benches originating at the mouths of the streams coming out of the mountains. These benches extend up to 4 or 5 miles out in the valley and rise more than a hundred feet above the Valley formed at present. At the mouths of some of the larger mountain streams alluvial fans have been deposited and slope down to the benches.

The material ranges in size up to 6 inches. Material of greater size is present, but it is a minor part of the whole. The rocks farther down towards the valley are well rounded indicating stream action. But as we progress further back towards the mountains, the material becomes more and more angular.

The Tertiary lake beds are a composite of all the formations in the area as far as mineralogy is concerned. The material is a totally loose type, indicating that silicification and consolidation has been negligible. There is a predominance of granite and Cretaceous igneous material over the Quadrant quartzite and Tertiary lava in the gravels.

These beds have been correlated with the Bozeman lake beds containing Pliocene fossils, the Silver Bow Valley south of Butte carrying upper Miocene fossils, and the Smith River deposits east of Helena correlated with the middle Miocene. In this part of Montana, a period of valley filling existed during the greater part of the Miocene and Pliocene, followed by a period of crustal disturbances which in many cases remodeled the drainage systems, and disturbed the gradients so that now the older deposits are usually trenched by the present streams.

These gravels are certainly Tertiary and probably not far from the end of the Miocene.

Historical Geology

The first record of geological activity in this part of Montana was the deposition of formations of the Algonkian Period, red sandstones, calcareous shales and impure limestones.

An angular unconformity between the Flathead and Algonkian formations indicates the termination of Belt sedimentation by an extensive uplift (Killarney Revolution) which was followed by a long period of erosion before the Flathead quartzite was deposited in middle Cambrian times.

Alternate advance and retreat of the sea caused the series of the following beds: Wolsey shale, Meagher limestone, Park shale, Pilgrim limestone, Dry Creek shale, and Yogo limestone.

At the top of the Cambrian there is another unconformity, for the upper Devonian lies on the Cambrian. The Ordovician and Silurian sediments are missing. The shallow seas of the middle of this period were the seat of the deposition of the Jefferson limestone, and with the recession of the seas, the Three Forks shale was laid down.

During the Mississipian period the Madison limestone was deposited. The Amsden formation, shales deposited over southwestern Montana during upper Mississippi times, is missing in this part of Montana.

Triassic age rocks are entirely missing due to one of two conditions, either the sediments were not deposited or else they were removed by erosion. The Jurassic seas were all shallow and the sediments comprising the Ellis were deposited near the shore line. The material comprising the Kootenai Cretaceous formation was deposited in a large fresh water lake.

The period from the late Cretaceous to the early Tertiary was one of great crustal disturbance. Associated with the disturbance was large-scale igneous activity. The several eruptions and intrusions are intimately related to the great mountain making epochs of the Laramide disturbance, as may be seen by reference to the following chronological table (ref. 2, p. 231).

"1. Middle Cretaceous. Period of main Rocky Mountain folding, and formation of the large earth-folds in northwesterly direction.

2. Middle-Upper Cretaceous. Extensive erosion and beveling of folds.

3. Upper Cretaceous. Andesite eruption, Deposition of extrusive lavas and breccias west of Rocky Mountain front and formation of tuffs and andesitic sediments on the plains.

4. Upper Cretaceous. Local intense erosion and formation of coarse andesite conglomerates.

5. Upper Cretaceous. Thrust faulting along northwest lines, and local intensification of folding.

6. Eocene (?). Intrusion of Boulder Granite Batholith.

7. Eocene. Extensive erosion, approximating peneplanation.

8. Oligocene, Miocene. Normal faulting ; accumulation of river gravels and lake silts and gravels, early rhyolite.

9. Pliocene. Same conditions, with extrusion of later rhyolite and dacite.

10. Pleistocene. Two or more glacial stages in the mountains."

The boulder batholith represents the middle phase of an igneous cycle that during Cretaceous and Tertiary times was one of the dominating geologic events of the Montana Rocky Mountain region. The rock types of closely associated eruptions pass through a similar sequence; first, gabbro, diabase, andesite; second diorite, quartz-monzonite, aplite; and third, dacite and rhyolite.

The geological history of the Smoke Hollow area began with the Laramide disturbance that folded the beds, probably forcing the Paleozoic and Mesozoic formations into their present-day atitudes. Faulting accompanied the disturbance. This was followed by Cretaceous andesite and basalt flows. Following a period of erosion, several rhyolitic flows covered the area and lay locally unconformable on the earlier flows. It was at this time that the Boulder batholith intruded and stoped its way near to the surface. Since then erosion has been the dominating factor. The Deer Lodge valley had been dammed at its southern extremity by uplift. A lake was formed and as erosion wore down the adjacent ridges and mountains, the material was deposited as lake beds. After the lake drained by stream erosion of the barrier at its outlet, the material eroded from the highlands has been deposited as alluvial fans spreading out from the stream mouths. Benches have been formed along the valley by Deer Lodge River which has cut down the original lake bed floor.

Plate 19.

(a) Quadrant quartzite.

(b) Cretaceous lavas.

(c) Quartz monzonite.

(d) Tertiary lava.

This subsequent erosion has exposed the Quadrant Quartzite buried by the lava flows. The lava flows themselved have been eroded for the most part, leaving ridges. The exposure of the Boulder batholith has been dissected by streams and greatly eroded down.

Elk Mine

The only prospect in the area is the Elk mine in the SW corner sec. 9, T. 6 N., R. 9 W. The mine name is not certain.

The mine consists of two shafts and a possible raise, the workings connected by a drift. Shafts 1 and 2 are on the east side of the road, while the raise is west of the road. The largest dump is about 120 x 15 feet and 20 feet high at the north end. Shaft 2 has a dump approximately 40 x 40 feet and 5 feet high. Working number 3 was determined to be a raise because no mine dump was present at the collar. The total horizontal length of the workings probably doesn't exceed 400 feet. A strike reading on the mine gave N 85 degrees W while the dip was read as 75 degrees north.

The mine is located in the quartz monzonite of the Boulder batholith. The workings apparently follow a mineralized fracture that is 2 feet wide at shaft 1, 2 to 3 feet wide at shaft two and 2½ feet wide at collar of raise 3.

The quartz monzonite near the fractures is sericitized, highly kaolinized, and iron stained. Most of the country-rock on the dumps seems to be fresh, but the petrographic microscope reveals them to be well altered.

The minerals lie in a number of irregular quartz stringers. There is a sharp contact between the quartz and grainte in some cases, while the contact is gradational elsewhere.

Paragenisis

The author is of the opinion that the deposit is a fissure filling resulting from hydrothermal action. Next to the altered wall rock, there is a layer of crystals of quartz up to about ¼ of an inch long. At the same time quartz filled up smaller fissures up to ½ inch wide that grade into the monzonite. Interspaced between the quartz grains are well developed pyrite grains. They are few but one of the crystals is almost ½ inch across. Next to the quartz in the open fissure there was a deposit of about 2 inches of an iron carbonate. This was identified by mineralogical tests to be ankerite Ca CO_3 (Mg, Fe, Mn) CO_3. It is a dark brown almost cherty mineral with rhombehedral cleavage. Covering ankerite is a thin 1/8 inch layer of drusy quartz. This was the last deposit so indications were such that the fissure still hadn't been entirely filled with this last quartz deposit.

The wall rock is moderately altered by hydrothermal action. Sericitization and kaolinization were the noticeable effects. The alteration couldn't be recognized more than a foot awy from the vein.

Spongy limonite was found in the dump. This was probably what the outcrop must have been composed of. This gossan probably represented the remains of leached sulfides. The workings and dumps indicate that the mineralization failed to show value with depth and the mine was abandoned.

Summary

The purpose of this thesis was to map the contact of the Boulder batholith and adjacent formations in the Smoke Hollow area near Deer Lodge, Montana. The author advanced the batholith contact about 2 miles north of that same contact as mapped in previous geologic data of the area. At the same the structure of the area was studied to the limited extent possible in the small local area.

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